NASA Range Safety Program
2006 Annual Report

STATUS REPORTS
JOHNSON SPACE CENTER
SPACE SHUTTLE RANGE SAFETY PANEL

The Space Shuttle Range Safety Panel has been involved in a number of activities over the past year. The panel supported three STS launches, launch area risk assessment, solid rocket booster aft segment analysis, flight termination system frequency change as well as hosting the range safety tool summit. The Columbia Debris Catalog Project and Flight Operations Version 1 software impacts to shuttle flight dynamics were also addressed.

Support of Shuttle Launches, Launch on Need, and Entry Level Safety Activities

Range Safety supported three launches in 2006 in addition to the Launch on Need rescue mission planning and entry safety activities.

STS-121. STS-121 was the first International Space Station mission to fly with a low dynamic pressure target. This change in mission profile came after the high dynamic pressure Range Safety design was complete and required some data redelivery to the 45th Space Wing so their displays could be updated for the new disposal areas. Launch day support was nominal.

STS-121 was also the first flight to have the protuberance air load ramps removed from the external tank. The Lockheed Martin Manned Space Systems assessment of this configuration with the performance enhancements certified external tank entry trajectories resulted in a violation of the external tank rupture altitude requirements (NSTS-07700 Volume X, *Space Shuttle Flight and Ground System Specification*.)

Range Safety developed new external tank entry trajectories based on current International Space Station mission profiles and presented the methodology and results to the Space Shuttle Program and the Range Safety panel. Lockheed Martin Manned Space Systems was able to use the new trajectories to clear the Volume X requirements and resolve the issue for STS-121. Subsequent flights that have the protuberance air load ramp removed from the external tank can use the new trajectories to clear the Volume X requirement.

STS-115. STS-115 products were delivered according to standard process. Due to data hits on launch day, the real time support team was required to use contingency procedures to make a determination of the potential for debris impacts on land. The anomaly and the resulting updates to Range Safety real time processes were reviewed and approved at the Range Safety panel.

STS-116. STS-116 products were delivered according to standard process. Another launch day issue required Range Safety support to use the newly implemented (post-STS-115) backup procedures to obtain the required vector for debris land impact evaluation. By using this procedure, Range Safety's launch day customers received their data within the standard delivery time.

Launch on Need Rescue Missions. Each Space Shuttle Program mission is now paired with a Launch on Need rescue mission. The Range Safety production community

engineered a generic 51.6-degree Launch on Need rescue mission delivery package consisting of the ascent destruct criteria and the disposal document. The Range Safety team presented the process and received approval from the Range Safety Panel on 8 August 2006.

The current Range Safety delivery process was tailored to reduce generation and quality assurance time while continuing to meet customer expectations. To ensure the applicability of the generic data for each future 51.6-degree Launch on Need International Space Station rescue mission, the Range Safety Team established detailed verification criteria. The verification criteria were discussed with the external customers and the flight design community.

The criteria were created to verify the applicability of generic data for each future 51.6-degree Launch on Need International Space Station rescue mission. The generic delivery package is robust and should cover all 51.6-degree Launch on Need International Space Station rescue missions through the end of the Space Shuttle Program.

Entry Range Safety Activities. The Space Shuttle Program continued support of entry range safety activities by providing two products for each of the Shuttle missions of 2006. First, the Space Shuttle Program generated expectation of casualty estimates for all potential landing opportunities for this year's missions before launch and updated these estimates daily during the last three flight days for each mission. STS-116 marked the first flight where Kennedy Space Center on-site risks were modeled with sheltering effects included.

Second, the Space Shuttle Program improved its coordination with the Federal Aviation Administration in its continuing effort to keep the Administration aware of Shuttle landing opportunities and potential debris footprints in the case of an incident during entry, so that the Federal Aviation Administration may best manage risk to the airborne public during such incidents.

Updated Inputs to Launch Area Risk Assessment

The updated launch area risk assessment effort is nearly complete. The Panel is continuing to work through the remaining open work such as space shuttle main engine failure rates and the certification of the Air Force's Monte Carlo Launch Area Risk Assessment tool. The Panel is reviewing the risk input table mission, specifically to ensure concurrence between the 45th Space Wing and NASA on the inputs and the resulting risk results. New launch area risk calculations have shown a decrease in launch area risk of two orders of magnitude. Open work includes that mentioned as well as NASA concurrence on the verification of the 45th Space Wing Launch Area Toxic Risk Assessment "3D" toxics modeling.

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Solid Rocket Booster Aft Segment Analysis

Previous studies have shown that the intact solid rocket booster aft segment accounts for more than 90 percent of the overall launch area risk. The explosive yield that results from the aft segment impacting the ground is estimated using several different assumptions. One of these assumptions involves the orientation of the aft segment at the time of impact. Another assumption pertains to the amount of propellant that is burned post-destruct. The combination of these two assumptions can significantly alter the casualty expectation values that are computed. Improving the accuracy of aft segment modeling will enhance the accuracy of the overall risk estimates.

In the spring of 2006, the 45th Space Wing presented the results of a study that analyzed solid rocket booster aft segment post-destruct burn rate and impact orientation to the Space Shuttle Range Safety Panel. The results showed that the propellant in the aft segment is expected to stop burning once destruct action is taken and the chamber pressure is released. Furthermore, the analysis results indicated that the aft segment would likely impact the ground with an angle of attack of ~70º for most failure cases after about 10 seconds mission elapsed time. The Space Shuttle Range Safety Panel is currently performing a peer review of the 45th Space Wing analysis results. Once the peer review is complete, the panel will propose a strategy for implementing the analysis results into future launch area risk assessments.

Flight Termination System Frequency Change

In March 2000, the National Telecommunications and Information Administration directed all federal test ranges to move flight termination system operations from the 406.1 - 420.0 megahertz frequency band to the 420.0 - 450.0 megahertz frequency band. Currently, the Shuttle operates on a command frequency of 416.5 megahertz.

In July 2005, the Shuttle Program Requirements Control Board decided to request a waiver of the requirement to move off of the current Shuttle frequency. In early 2006, the Space Shuttle Range Safety Panel coordinated the effort to request the waiver, and in September 2006, a National Telecommunications and Information Administration letter to NASA stated approval of the waiver to allow the Space Shuttle Program to continue flight termination system support on the current frequency until the end of the program in 2010.

The approval of the waiver was based on the assumption that development of a replacement launch vehicle will continue, and the new launch vehicle will use a flight termination system frequency other than the 406.1-420.0 MHz frequency band.

NASA Agency Range Safety Tool Summit

The Space Shuttle Program hosted the first Agency Range Safety Tool Summit in September 2006. This meeting was proposed by the Agency Range Safety Manager

and the Office of Safety and Mission Assurance to minimize duplicate efforts occurring at the five NASA Centers that currently perform range safety analyses for ascent and entry. In addition to Headquarters' Office of Safety and Mission Assurance, each Center that has a range safety tool (Kennedy Space Center, Dryden Flight Research Center, Wallops Flight Facility, Jet Propulsion Laboratory, and Johnson Space Center) was represented.

The attendees discussed the capabilities of each Center's tool and decided to explore using Dryden's joint advanced range safety system as the overall integration tool for the Agency. First, Wallops' sounding rocket range safety toolset and the Space Shuttle Program's public entry risk assessment toolset will be integrated into the joint advanced range safety system as trial cases. If successful, the joint advanced range safety system will become the official overall integration tool for the Agency, ultimately hosting both the Space Shuttle Program's ascent and entry risk assessment toolsets. The Space Shuttle Program is considering a handful of minor actions and continues to work with the Agency in development of a common toolset.

Columbia Debris Catalog Project

The Columbia Debris Catalog Project is a joint effort between the Federal Aviation Administration and NASA, made possible under Memorandum of Agreement No. FNA/10-02-01, KSC No. KCA 2055. The purpose of the project is to study the recovered Columbia debris to facilitate realistic estimates of the risk to the public. To accomplish this goal, current debris modeling assumptions must be compared and validated against real data events. The Columbia accident allows experts to use a real data event to analyze an entry breakup event and facilitate further studies on adjusting current debris risk modeling assumptions and techniques.

Approximately 90,000 debris pieces have been recovered and more are being collected on a weekly basis through the Columbia Research & Preservation Office located at Kennedy Space Center. Although the debris collected at the time of recovery in 2001 were cataloged, no piece contained sufficient characteristic data required for further debris risk modeling analysis. In 2004, this project was started and through many requirements review cycles and budgetary constraints, the USA/Change Partnering Agreement was signed on 20 July 20 2006 to begin work on collecting debris data for this project.

With a total project budget of $145,000, work began in August 2006. The project was divided into two different phases. Because the proposed data collection process was brand new, the team decided a trial run to test the procedures would benefit any Phase II effort by increasing efficiencies in time and cost. Phase I included a two-week debris processing period with two full-time dedicated personnel. During that period, 167 debris pieces were processed. The processing team tested the requirements, acquired and tested the hardware, tested the layout of the facility, and tested and improved the procedures. The results of Phase I provided the team with sufficient throughput data and processing recommendations to make preliminary recommendations for Phase II.

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The Federal Aviation Administration and NASA team will recommend data collection on the remaining debris starting with all "boxed" debris that contains approximately 50 percent of the total recovered. (Crew module debris will not be processed.) Depending on the resources available, a four person processing team could potentially catalog 16,640 pieces per year without unforeseen project interruptions. At this rate, all recovered debris could potentially be catalogued in 5.4 years.

Pilot Tone

To date Kennedy Space Center has tested the range safety system pilot tone during multiple integrated operations for STS-114, 115 and 116. Testing has occurred during integrated pad operations but not during S0007, launch count down operations, due to the difficulties related to developing launch commit criteria. Currently, the Eastern Range has come forward with the position that they will not require pilot tone for the remainder of the Shuttle program. Launch Operations is waiting for an official memo from the Eastern Range. Once that has been received, the Panel will pursue canceling implementation of pilot tone for shuttle and closing the current program change request.

Flight Operations Version 1 Software Impacts to Shuttle Flight Dynamics

Per Program Requirements Document specifications, Wallops Flight Facility's high-speed C-band tracking data should be transmitted to Johnson Space Center uncorrected for refraction. However, during the flight of STS-114, it was discovered that the tracking data provided by the Range Operations Control Center Flight Operations Version 1 (FOV1) software was corrected for refraction. A software fix request was submitted to the FOV1, requesting that Wallops high-speed tracking data be provided to Johnson Space Center uncorrected for refraction. The implementation of the fix is not expected to occur for another 2.5 years according to the latest estimate provided at the 14 November 2006 Range Safety Panel meeting. Until the implementation is in place, Wallops high-speed data will continue to be provided to Johnson Space Center corrected for refraction, and the Mission Control Center software correction will not be used.

The FOV1 correction model is based on one modulus of refraction value for the entire year that is representative of a summer/fall atmosphere. To quantify the effects of using a single modulus of refraction on the high speed tracking data, USA Navigation performed an analysis comparing the FOV1 refraction correction to the Mission Control Center refraction correction. The results revealed that while the differences were small for the summer/fall months (June through November) when the FOV1 modulus of refraction closely resembles the Mission Control Center modulus of refraction, they were significantly larger—on the order of 1,500 feet in radial position and 15 feet/second in radial velocity—for December through May.

Operationally, the high speed tracking data will still be able to provide a state vector to correct gross onboard navigation errors. However, during the winter/spring months, the vectors will likely not be of sufficient quality to update the onboard state to correct for

small planar dispersions that may have built up during powered flight (Flight rule A 4-57 F).

Launch Area Toxic Risk Assessment "3D" Certification and Implementation

The 45th Space Wing is in the process of developing a strategy for certifying and deploying Launch Area Toxic Risk Assessment "3D," a new combined debris and toxics model for Shuttle launch area risk assessment applications. The Space Shuttle Range Safety Panel will identify the appropriate personnel to assist with the evaluation and peer review of the Launch Area Toxic Risk Assessment "3D" software. The panel will coordinate the effort to implement the new model into future launch area risk assessments to achieve more accurate public risk estimates.